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Predicting patients that require care at a trauma center: Analysis of injuries and other factors

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ABSTRACT

Introduction: The detection of occult or unpredictable injuries in motor vehicle crashes (MVCs) is crucial in correctly triaging patients and thus reducing fatalities. The purpose of the study was to develop a metric that indicates the likelihood that an injury sustained in a MVC would require management at a Level I/II trauma centre (TC) versus a non-trauma centre (non-TC).

Methods: Transfer Scores (TSs) were computed for 240 injuries that comprise the top 95% most frequently occurring injuries in the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) with an Abbreviated Injury Scale (AIS) severity of 2 or greater. A TS for each injury was computed using the proportions of patients involved in a MVC from the National Inpatient Sample (NIS) that were transferred to a TC or managed at a non-TC. Similarly, a TS_{MAIS} that excludes patients with higher severity co-injuries was calculated using the proportion of patients with a maximum AIS (MAIS) equal to the AIS severity of a given injury.

Results: The results indicated for injuries of a given AIS severity, body region, and injury type, there were large variations in the TS_{MAIS}. Overall results demonstrated higher TS_{MAIS} values when injuries were internal, haemorrhagic, intracranial or of moderate severity (AIS 3–5). Specifically, injuries to the head possessed a TS_{MAIS} that ranged from 0.000 to 0.889, with head injuries of AIS 3–5 severities being the most likely to be transferred.

Discussion and conclusions: The analysis indicated that the TS_{MAIS} is not solely correlated with AIS severity and therefore it captures other important aspects of injury such as predictability and trauma system capabilities. The TS and TS_{MAIS} can be useful in advanced automatic crash notification (AACN) research for the detection of highly unpredictable injuries in MVCs that require direct transport to a TC.

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Introduction

In motor vehicle crashes (MVCs), initial detection of injuries can be problematic due to several factors including co-injuries, lack of external symptoms, and level of consciousness. The goal of the pre-hospital trauma system is to appropriately triage patients such that they receive the "right treatment" at the "right place" and at the "right time". The triage of a patient is affected by many factors including the severity, time sensitivity, and predictability of their injuries [1–4]. Predictable injuries are those injuries that are identifiable by emergency medical personnel upon arrival at the scene of a crash while unpredictable, or occult, injuries are not immediately detected. An important part of triage is to identify such unpredictable injuries that would require treatment at a Level I/II trauma centre (TC) before the patient is taken elsewhere, i.e. a non-trauma centre (non-TC).

While triage of injured patients can be directed by prehospital protocols, significant proportions of patients are initially transported to a non-TC only to later require transfer to a TC for definitive care [5]. There can be significant limitations to definitive injury management at non-TCs due to a lack of surgical capabilities. As a result, the triage of patients with lower severity injuries to TCs is governed by limited resources and not injury

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severity. Therefore, triage systems or algorithms that use injury severity to predict TC transfer are limited by the lack of trauma system specific information. In the development of triage protocols and injury prediction algorithms such as advanced automatic crash notification (AACN) systems, useful models would confer the ability to predict which patients require TC care independent of injury severity. Given that injury severity alone does not predict who requires TC care, systems that more accurately capture the real-life patient transfer practices are required.

To identify those injuries that might be missed upon initial assessment, herein, we evaluate those injuries that were initially undertriaged. One explanation for patients taken to a non-TC and later transferred to a TC is that at least some less predictable injuries were not detected upon initial assessment. The objective of the study was to develop a metric that describes the likelihood that an injury is present in patients that require transfer from a non-TC to a Level I/II TC.

Methods

Top 95% AIS 2+ NASS-CDS injuries

The top 95% most frequently occurring injuries in the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) for the years 2000–2011 with an Abbreviated Injury Scale (AIS-98) of 2 or greater were identified [6]. NASS-CDS provides a detailed record on a representative, random sample of thousands of minor to fatal tow-away crashes in the United States. For NASS-CDS 2009–2011 data, cases which involved motor vehicles with a model year older than ten years were excluded from the analysis due to missing occupant and injury information. After applying the exclusion criteria, the resulting NASS-CDS 2000–2011 dataset contained 54,703 cases, 94,283 vehicles, 115,159 occupants, and 303,230 injuries.

The resulting list of the top 95% most frequently occurring AIS 2+ injuries in NASS-CDS 2000–2011 (termed the "Top 95% List") contained 240 injuries. Inclusion of 100% of the AIS 2+ injuries from the same dataset results in 848 injuries. The severity, time sensitivity, and occultness of these 240 injuries have been previously characterised, and in this study the likelihood of each injury to be transferred will be quantified [1,2,4].

Transfer Score (TS)

A metric known as the Transfer Score (TS) was developed that indicates the likelihood that an injury is present in patients transferred from a non-TC to a Level I/II TC. The National Inpatient Sample (NIS) for the years 1998–2007 was used to calculate a TS for each of the injuries on the Top 95% List [7]. The NIS is a database that contains hospital discharge data from approximately eight million TC and non-TC stays each year and is supported by the Healthcare Cost and Utilization Project (HCUP). The NIS contains patient injury information coded with the ICD-9 lexicon. The TS was calculated using the MVC subset of the NIS which is specified by E codes 810–819 with a post-dot decimal of 0 or 1 corresponding to MVCs involving drivers and passengers.

Levels I and II TCs were grouped together for this study because they provide comprehensive trauma care for seriously injured patients and have immediate availability of trauma surgeons, anaesthesiologists, and other specialists. According to the American College of Surgeons Committee on Trauma Classification System of Trauma Center Level, Level II TCs must meet essentially the same criteria as a Level I except for the volume performance standards of 1200 admissions a year, or 240 major trauma patients per year, or an average of 35 major trauma patients per surgeon [8]. In literature, Levels I and II TCs are typically analysed together since the criteria are essentially the same [9,10].

A list of all unique hospitals in the NIS was compiled to classify the hospital as a Level I/II TC or non-TC. The presence of a Level I or II designation is determined by state regulatory agencies and then may be verified by a third party such as the American College of Surgeons (ACS). For the purposes of this study, state designated Level I or II centres with or without ACS verification were classified as TCs, with all other hospitals being classified as non-TCs. Levels I and II TCs provide comprehensive trauma care with an adequate depth of resources and personnel with an immediate availability of trauma surgeons, anaesthesiologists, and other physician specialists [8–10]. Classification of the trauma designation was completed using a list obtained from the Trauma Information Exchange Program (TIEP) and through manual verification [11]. This was a non-trivial task which substantially augments the NIS database and the ability to do TC versus non-TC related research. The complete list of hospitals in the NIS database contains 3872 unique hospitals. Of these hospitals, 64% (2483) included the hospital name. Classification of trauma designation was completed using the list from the TIEP (22%, 552) and manually (78%, 1930) using the ACS website, state-level trauma designation websites, and individual hospital websites. Six researchers were involved in the manual classification procedure with one researcher verifying the entire list. The reproducibility of the classification was deemed sufficient. Two researchers each classified 100 hospitals and the inter-observer agreement was 100%. At the conclusion of the classification, 2381 hospitals with corresponding trauma centre classifications were included in the study. 102 hospitals were excluded from the study because there was missing information, the hospital was no longer in operation, or the TC treated paediatric patients only.

Patients were subsequently stratified into the following groups: (1) transferred from a non-TC to a TC or (2) managed at a non-TC. Patients admitted directly to a TC were excluded from the analysis due the bias of patients with lower severity injuries being treated at a TC due to the proximity of the TC [12,13]. An AIS-98 to ICD-9 mapping approach was used to match each of the ICD-9 codes present in the NIS with its corresponding AIS code [14]. Of the 240 injuries on the Top 95% List, 235 injuries were mapped to AIS codes and represented in the NIS. The five injuries with missing data were assigned the median value of the TS distribution of the remaining 235 injuries to maintain the distribution of all the injuries. The five injuries were relatively uncommon accounting for the top 85% or higher on the Top 95% List.

For each injury, the proportion of patients in each of these groups was determined by dividing the number of patients in one group by the total number of patients in both groups as shown in Eqs. (1) and (2):

$$\text{Proportion of patients transferred to TC} = \frac{\text{Patients transferred to TC}}{\text{Patients transferred to TC} + \text{Patients managed at a non-TC}} \quad (1)$$

$$\text{Proportion of patients managed at a non-TC} = \frac{\text{Patients managed at a non-TC}}{\text{Patients transferred to TC} + \text{Patients managed at a non-TC}} \quad (2)$$

A TS for each injury was calculated by determining weighting factors for each of the proportions (x_1: managed at a non-TC and x_2: transferred to TC). Based on the distribution of the proportions of the 235 injuries, weighting factors, x_1 and x_2, were calculated by

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